Fluid Resuscitation in Modern Combat Casualty Care: Lessons Learned from Somalia

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The medical issues faced by military medics in the combat environment frequently represent a significant variation from their training and civilian experience. The differences between care delivered by military medics under fire and care rendered by civilian medics are profound. The lessons assimilated from extensive discussion and focused conferences form the basis for the proposed changes in combat prehospital care. These differences revolve around a lack of basic monitoring capability, significant logistical constraints, and prolonged evacuation times. The resuscitation algorithm presented in this article represents a consensus of military and civilian trauma experts.

Key Words: **Fluid resuscitation, Combat casualty, Algorithm, Somalia.**

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On October 3, 1993, in a daytime raid into the densely populated Black Sea area of the city of Mogadishu, Somalia, U.S. soldiers were caught in a firefight, helicopters were shot down, and a resupply column was ambushed. Approximately 200 U.S. soldiers were involved, and of these, almost two thirds were injured. Many were taken care of by medics for hours in the streets of Mogadishu. Fourteen died before they could be evacuated from the battlefield; three died in the 46th Combat Support Hospital, and one died several days later in Germany. Mabry and colleagues have previously described the details of this event.[1]

The medical issues faced by the medics in the field in Mogadishu were unique in recent military experience. Recognizing this, several conferences were held to capture the lessons learned and develop strategies applicable to future conflicts. The first medical review was held in Mogadishu 2 days after the battle was over. Although no published record of that review exists, the discussions held that day were echoed in the more conventional conferences convened over the following years. The first focused discussion was held at the Special Operations Medical Association in December 1998. These proceedings were published as a supplement in *Military Medicine*.[2] Next, a conference entitled "Combat Fluid Resuscitation 2001" was organized at the Uniformed Services University of the Health Sciences, Bethesda, Maryland, June 18–20, 2001. The lessons assimilated from these conferences, and others, along with extensive discussions with medics and military surgeons form the basis for the proposed changes in combat resuscitation discussed in this article.

BACKGROUND: RECENT HISTORICAL PERSPECTIVE

The return of experienced military surgeons into civilian surgical practice facilitated the widespread transfer of trauma lessons derived from the Vietnam conflict into civilian practice. These included dedicated helicopter transport, development of trauma teams, and specialized services and trauma centers focused on injured patients. Emergency Medical Services developed protocols for prehospital treatment of trauma patients with two large-gauge intravenous (IV) lines, rapid crystalloid resuscitation, and cervical collar and spine board immobilization. Although not practiced on the battlefields of Vietnam, this civilian approach seemed appropriate for the predominately blunt-injured civilian patient population, and by the mid 1980s had become a standard of care. Concurrently, many Department of Defense hospitals stopped receiving civilian regional patients, whereas in those still receiving trauma patients, training and experience became largely civilian oriented. Although appropriate for civilian trauma, the civilian standards were found wanting in the combat military setting.

PRIMARY LESSON LEARNED

The primary lesson learned during the Task Force Ranger deployment and mass casualty experience in Mogadishu was the recognition that military field medical care is different from civilian urban medical care. This should be obvious but, as in previous conflicts, civilian procedures must be "unlearned" and military medical practice reformed to fit the tactical situation.[3]

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COMBAT VERSUS CIVILIAN TRAUMA DIFFERENCES

In 1984, COL Ronald Bellamy, in his article "The Causes of Death in Conventional Land Warfare: Implications for Combat Casualty Research," challenged the military medical community to face these issues, but by 1993, very little attention had been paid to the differences in military prehospital versus civilian prehospital care.[3] Most reviews from the Gulf War did not emphasize the prehospital care of combat casualties. Many military physicians, nurses, and medics had little trauma care experience; those that had, in general, gained this in strictly civilian environments, not necessarily appropriate to the military setting. Medics were trained to immobilize the cervical spine, establish intravenous access, and give IV fluids to combat casualties in accordance with civilian prehospital care guidelines, regardless of the mechanism of injury or tactical or logistical situation.[4,5] Nurses were not trained or expected to function independently. Most military surgeons, although familiar with civilian-style trauma triage and resuscitation, which routinely devote major resources to near-moribund patients, had little recent experience with the realities of military resuscitation and triage.[6]

Over the years after the Battle of the Black Sea, the medical experience in Mogadishu was reviewed in detail. Salient issues that emerged were that improved methods of hemorrhage control, better trauma training, and new approaches to resuscitation were required.[7] Fortunately, in the next 3 years, the results of four lines of research were published, each of which had profound potential for military medical readiness and which would significantly influence efforts to redirect teaching and practice regarding prehospital care for military trauma.

HYPOTENSIVE RESUSCITATION

The first of these articles was published in 1994, in the *New England Journal of Medicine*.[8] William Bickell and his colleagues described a no-fluid resuscitation protocol in hypotensive urban patients after penetrating truncal injuries and concluded that traditional rapid fluid resuscitation decreased survival in these patients. These findings corroborated those found by Cannon and Beecher during World War I and World War II.[9–11]

HEMORRHAGE CONTROL

In 1995, Michael Larson and his colleagues from the Letterman Army Institute of Research published a pivotal animal experiment in the *Archives of Surgery* demonstrating that a new dry fibrin sealant dressing provided superior hemostasis compared with traditional gauze dressings.[12] This work initiated the effort to provide improved hemorrhage control to front-line medics and surgeons.

TACTICAL MEDICINE

In 1996, CAPT Frank Butler and his group described in *Military Medicine* an approach to prehospital military medical care (care under fire, tactical field care, and casualty evacuation care) that could be integrated appropriately into various tactical situations.[13] After review by the American College of Surgeons, Committee on Trauma, this tactically driven approach for prehospital care in the military environment was included in the *Prehospital Trauma Life Support Manual*.[14]

CONTROLLED RESUSCITATION

Finally, in 1999 Burris et al. published in the *Journal of Trauma* an elegant rat study describing controlled resuscitation for uncontrolled hemorrhage.[15] Bleeding and mortality were increased with standard resuscitation back to a normal blood pressure, whereas no resuscitation resulted in increased mortality. They conclude that controlled fluid use and moderate hypotension improved survival. These four lines of thinking and research—resuscitation practice that was both evidence-based and economical, new and potentially field-ready methods of hemostasis, and guidelines for resuscitation practice appropriate to the realities of battle situations—were crucial responses to the challenge for improving combat casualty care delineated by Bellamy in 1984.

The algorithm for fluid resuscitation in military prehospital situations presented below is grounded in the critical differences in civilian and military care environments, the need for improved hemorrhage control, the optimization of fluid use, and resuscitation endpoints obtainable by the military medic providing care in the forward area. This approach represents a consensus not only of the experienced military and civilian trauma surgeons and medics that attended the Combat Fluid Resuscitation 2001 conference, but many others who have also reviewed this approach in less formal venues. The differences between care delivered by military medics under fire and care rendered by civilian medics are profound. These differences are the basis for this work.

CONSENSUS ASSUMPTIONS BASIC TO THE PROPOSED RESUSCITATION STRATEGY

1. The tactical situation may or may not allow even abbreviated medical care to proceed. Medical care may consist solely of rapidly moving the patient into a ground vehicle or helicopter and evacuating in extremis.
2. Lack of hemorrhage control is the leading cause of preventable death on the battlefield. Improved hemorrhage control is therefore of paramount importance. This may include the temporary use of arterial tourniquets, and in the near future may include the new hemostatic dressings[16] and possibly injectable methods of hemostasis.[17] Use of a temporary tourniquet, as described by Butler et al., has become standard practice in Special Operations medical practice and is currently taught to all Special Operations medics.[2,13]
3. Stethoscopes and blood pressure cuffs, mainstays of civilian prehospital care, are rarely available or useful to the front-line medic in the typically noisy and chaotic battle-

field environment. As the stethoscope is rarely available on the battlefield, a palpable radial pulse and normal mentation are acceptable alternative resuscitation monitors and, more importantly, tactically relevant endpoints to either start or stop fluid resuscitation. Both can be adequately assessed in noisy and chaotic situations.

4. IV access is important for delivery of fluids and medication and should be obtained early, on any casualty with significant injury. However, only those casualties meeting criteria (described below) for resuscitation are given fluids. IV access is distinct from delivery of IV fluids. Most casualties will only require the IV access for pain medication and antibiotics. Casualties with significant injuries should have a single saline lock started with an 18-gauge catheter, as early as safely possible. One access portal is sufficient, thus conserving supplies and time.
5. When IV access is not obtainable, modern intraosseous fluid delivery systems are a reasonable substitute for IV access and a major improvement over venous cutdowns.[18] Intraosseous systems have been successfully used in military operations since at least World War II.[19] Most recently they were used in Afghanistan after repeated failed attempts at IV access (K. O'Conner, personal communication). Conversely, cutdowns are time consuming, technically difficult, and require instruments. They are not appropriate for military prehospital use; medics will not be trained or equipped for prehospital use of this procedure.
6. Only those casualties meeting criteria for resuscitation are given IV fluids. The capacity for prehospital fluid resuscitation depends on the amount—both weight and volume—of fluid that can be carried by each medic and characteristics intrinsic to the fluid itself. Mission constraints will dictate how much fluid is available on the battlefield.
   a. Some medics currently carry up to six 1,000-mL or 12 500-mL bags of fluid.
   b. One 1,000-mL bag of lactated Ringer's (1,100 g or 2.4 lb), 1 hour after injection will expand intravascular fluid volume by approximately 250 mL; one 500-mL bag of Hetastarch (591 g or 1.3 lb), in a similar time period, expands intravascular fluid volume by approximately 800 mL.[20,21] One bag of Hetastarch is functionally equivalent to three bags of lactated Ringer's, whereas there is almost a sixfold advantage in the overall weight/benefit ratio (1.3–7.2 lb, respectively). This expansion is sustained for up to 8 hours.[13]
7. Other prehospital therapeutic interventions are focused by the same concerns as those for hemostasis, fluid resuscitation, and logistics. Training and supplies for needle thoracentesis, pain control (including IV morphine and splinting), and IV antibiotics are both necessary and sufficient and can be appropriately tailored to the exigencies of tactical situations. These concepts are standard practice for the Special Operations medic and are described by Butler et al.[13] Conventional military medics are trained in many of the same procedures.[22]

RECOMMENDED CONSENSUS ALGORITHM OF FLUID RESUSCITATION FOR COMBAT CASUALTIES

The algorithm presented below represents a consensus developed by a multidisciplinary approach over the last 9 years, and was presented at the Special Operations Medical Conference (conference proceedings in *Military Medicine*, 1998).[2] The summary documents presented in these proceedings are similar. Recently (August 2002), the United States Special Operations Command, Tactical Combat Casualty Care Committee (a multidisciplinary committee of military and civilian trauma experts) have extended these recommendations to include Hextend as the resuscitation fluid of choice.

1. Superficial wounds (> 50% of injured): No immediate IV access or fluid resuscitation is required.
2. Any significant extremity or truncal wound (neck, chest, abdomen, or pelvis) with or without obvious blood loss and irrespective of pulse character:
   a. If the soldier is coherent and has a palpable radial pulse, blood loss has likely stopped.
   b. Start a saline lock; hold fluids; reevaluate as frequently as situation allows.
3. Significant blood loss from any wound *and* the soldier either has no palpable radial pulse or is not coherent (note: mental status changes resulting from blood loss only, *not* head injury):
   a. *STOP THE BLEEDING*: Direct pressure—hands and gauze rolls, with or without adjuncts such as Ace bandages—are the primary methods. In addition, various advanced hemostatic dressings will soon be available. Extremity injuries may require temporary use of an effective arterial tourniquet. However, > 90% of hypotensive casualties suffer from truncal injuries, not amendable to either of these strategies.
   b. After hemorrhage is controlled to the extent obviously possible, obtain IV access and start 500 mL Hextend (one bag).
      i. If the casualty's mental status improves and a palpable radial pulse returns (a positive response), hold fluids.
      ii. If no response is seen, give an additional 500 mL Hextend. If a positive response is obtained, stop fluids.
   c. Titrating fluids is desirable but may not be possible given the tactical situation. Likewise, the rate of infusion is likely to be difficult to control. On the basis of the effective volume of Hextend versus lactated Ringer's, no more than 1,000 mL of Hextend should be given to any one casualty (approximately 10 mL/kg). This amount is intravascularly equivalent to 6 L of lactated Ringer's. If the casualty is still unresponsive

and without a radial pulse after 1,000 mL of Hextend, consideration should be given to triaging supplies and attention to more salvageable casualties.

4. Based on response to fluids, casualties will separate themselves into responders, transient responders, and nonresponders.[23,24]
   a. Casualties with a sustained response to fluids probably have had significant blood loss but have stopped bleeding. These casualties should be evacuated at a time that is tactically judicious.
   b. Transient and nonresponders are most likely continuing to bleed. They need evacuation and surgical intervention as soon as tactically feasible. If rapid evacuation is not possible, the medic may need to triage his attention, equipment, and supplies to other casualties as determined by the tactical situation. No more than 1,000 mL Hextend should be given to any one casualty.
5. Head injuries impose special considerations. Hypotension (systolic blood pressure [SBP] < 90 mm Hg) and hypoxia ($SpO_2 < 90\%$) are known to exacerbate secondary brain injury. Both are exceedingly difficult to control in the initial phases of combat casualty care. Given current recommendations on the care of head injury, hypotensive resuscitation as outlined above for the soldier with obvious head injuries cannot be recommend.[25] The impasse for the forward area military medic is obvious and will have to be addressed as thinking and research on these issues progress.[26]

DISCUSSION

This effort is in keeping with the recommendation and greater than 50-year perspective offered by COL (Ret) Michael E. DeBakey from his *Military Medicine* publication entitled, "History, The Torch that Illuminates: Lessons from Military Medicine."[27] He states, "as in civilian medical practice, only by recording and analyzing military medical experiences can we apply the lessons of the past to future medical practice and improve the care of military personnel." The resuscitation outline presented herein summarizes the consensus of multiple meetings since the Somalia mass casualty episode.

Hypotensive resuscitation is not a new concept. Walter Cannon and John Fraser served with the Harvard Medical Unit in France in World War I, and E. M. Cowell served with the Royal Army Medical Corps. In 1918, in their article in the *Journal of the American Medical Association*, they describe their observations of fluid resuscitation:[9] "Injection of a fluid that will increase blood pressure has dangers in itself. Hemorrhage in a case of shock may not have occurred to a marked degree because blood pressure has been too low and the flow too scant to overcome the obstacle offered by the clot. If the pressure is raised before the surgeon is ready to check any bleeding that may take place, blood that is sorely needed may be lost." Dr. Cannon's endpoint of resuscitation before definitive hemorrhage control was a SBP of 70 to 80 mm Hg, using a hypertonic crystalloid/colloid mixture as his fluid of choice.

In World War II, H. K. Beecher and his colleagues developed Cannon's hypotensive resuscitation principles further in the care of consecutive combat casualties with truncal injuries:[10,11] When the patient must wait for a considerable period, elevation of his systolic blood pressure to about 85 mm Hg is all that is necessary. . .and when profuse internal bleeding is occurring, it is wasteful of time and blood to attempt to get the patient's blood pressure up to normal. One should consider himself lucky if a systolic pressure of 80–85 mm Hg can be achieved and then surgery undertaken.. . .In studies of the worst wounded drawn from 2,853 battle casualties that reached a hospital alive (a) None of the 2,853 died during surgery; (b) The over-all death rate at the 94th Evacuation Hospital in 1,623 men was 1.48%. . .; (c) The experienced surgeons dealing with these men were emphatic in their statements that these patients were "well prepared for surgery."

This approach was primarily an attempt to minimize transfusion volume and blood loss in the operating room. Large-volume crystalloid resuscitation, popularized by Moore and Shires,[28] extensively practiced in field hospitals in Vietnam, and subsequently recommended by Advanced Trauma Life Support,[24] became a de facto standard of care. An unintended consequence of this practice was the wide application of these principles into the prehospital military environment.

Recognizing this conundrum, and with supporting animal data, Bickell and his colleagues reported that an attempt to obtain normal blood pressures in trauma patients with truncal injury and SBP < 90 mm Hg only serves to increase bleeding, resuscitation volume, and mortality, and to decrease core temperature.[8] They demonstrated that, regardless of the victim's blood pressure, survival in an urban "scoop-and-run" rapid transport system with no attempt at prehospital resuscitation was just as good if not better than when such resuscitation was attempted. The relevance of a 15-minute urban civilian transport time versus up to 15 hours for a combat casualty is valid criticism of this work. A physiologic question that emerges from this effort is, how low a blood pressure can the injured casualty tolerate for how long? This includes both the potential for an initial hypotensive, hypoxic, reperfusion injury and the incidence of multiple organ failure 3 to 5 days after definitive operative repair and resuscitation.[29] Furthermore, should the hemoglobin substitutes be used as red blood cell replacement solutions or as true first-line resuscitation fluids? Similar questions are currently under investigation by Department of Defense Combat Casualty Care investigators. The answers should help clarify the duration of hypotension that can be tolerated in the injured soldier before definitive surgical care.

Relevant questions also must be asked about the other end of the blood pressure spectrum. At what level of resuscitation do clots "pop off" of spontaneously clotted vessels (H. L. Sondeen et al., unpublished data)? Does this point vary

with types of resuscitation fluid, time of onset, rate of resuscitation, and the nature of the wound? Data from an uncontrolled hemorrhage swine model (presented in this supplement, Sondeen et al.) suggest that the rebleeding point is an SBP of 94 $\pm$ 3 mm Hg (H. L. Sondeen et al., unpublished data). This endpoint does not appear to vary by aortic defect size or time and rate of resuscitation after injury. Furthermore, what really is the numerical relationship between blood pressure and pulse and the reliability of mental status as a marker of adequate volume status?[30,31] After considering the information from historical military medical sources, modern urban trauma studies, recent laboratory animal models, and a series of military and civilian expert trauma panels, it has been suggested that casualties without definitive hemorrhage control should have their blood pressure increased to a weakly palpable radial pulse, (potentially corresponding to an SBP of 80–85 mm Hg) to avoid the fatal consequences of rebleeding.

For the practicing military medic, the most important points in the resuscitation algorithm described above are (1) the emphasis on hemorrhage control, (2) the reliance on the purely clinical signs of a palpable radial pulse and mental status as indicators of perfusion rather than blood pressure measurement, (3) the judicious rather than overzealous use of fluids in hypotensive casualties, and (4) use of a low-volume colloid solution rather than the customary higher volume crystalloids. These points are an attempt to bring to the battlefield a trauma resuscitation strategy based on relevant civilian and military experience, current research, and the tactical and logistical realities of the modern dispersed battlefield. Integral to each step is reliance on the independent clinical and military judgment of an appropriately trained and experienced medic. This in turn may impose new requirements on the selection and training of these personnel.[32–34]

The resuscitation algorithm presented in this article differs slightly from that currently taught by Butler and others in the Navy Special Warfare Tactical Combat Casualty Care Course (TCCC) and described in the military medicine chapter in the *Prehospital Trauma Life Support* book.[14] Currently, Special Operations medics are trained to give 1,000 mL of Hespan to all casualties meeting the requirement for resuscitation. Modifying the TCCC to conform with the guidelines presented in this article is an improvement for at least three reasons: (1) logistics (not all casualties will require 1,000 mL Hespan, thus saving fluid and time for other casualties), (2) rebleeding (guiding the individual fluid requirements on the basis of a physiologic response may avoid the problem of inappropriate elevation of blood pressure and causing fatal rebleeding in previously clotted vessels), and (3) training (basing the fluid therapy on the premise of responders vs. nonresponders follows the lead of the American College of Surgeons Committee of Trauma Advanced Trauma Life Support course). An additional component of the TCCC teaches the nonmedical mission commanders that prehospital combat casualty care is significantly different from the care normally experienced in the controlled civilian environment.[35] Issues of triage, supplies, training, and experience are thus covered in terms that are intuitive to the nonmedical ground commanders.

The most glaring problem with the proposed resuscitation algorithm is that it likely cannot be rigorously evaluated in clinical trials. It is based on a combination of information from historical documents, current animal studies, civilian and military trauma experience, and expert opinion. This issue was extensively discussed during the Combat Fluid Resuscitation Conference, with unanimous agreement that this approach was sound. Furthermore, the realities of war prevent prospective, randomized, blinded resuscitation studies on the battlefield. As in the past, insightful observation, discussion, and recommendation from experienced military and civilian medics, surgeons, and scientists must provide the basis for military medical doctrine, with ongoing modification as further research and development generates new and relevant information.[11,36,37]

Although admittedly controversial, there is little convincing clinical evidence in trauma patients that any one crystalloid or colloid is "better" than others; however, there are absolutely clear logistic benefits for military medics to carry the smallest volume and weight of resuscitation fluid consistent with effective practice. For the near future, hypertonic saline dextran is not available; thus, Hextend is the next logical choice. Hextend has not been widely used as a frontline resuscitation fluid, and thus clear evidence of its superiority is lacking. However, hetastarch solutions mixed in saline (Hespan) increase blood loss compared with the identical hetastarch mixed in a balanced electrolyte solution, a lactate buffer, and with physiologic levels of glucose (Hextend).[38] Current recommendations are for the latter hetastarch solution. In addition, it is not clear to what extent ambient temperature or dehydration in the recipient alters physiologic response to this particular fluid. However, the ability of individual medics to triple their effective resuscitation capability, without increasing the volume or weight carried, justifies the tradeoffs outlined above. Furthermore, these small-volume resuscitation fluids may realistically allow the individual combatants to carry all of their own resuscitation fluid. As new Food and Drug Administration-approved fluids become available, similar logistical constraints and tactical assessments should apply.

SUMMARY AND CONCLUSIONS

The approach to resuscitation outlined above focuses on the casualties' physiologic responses to hemorrhagic shock rather than a specific injury. The main concern of the prehospital military provider is to recognize the casualty requiring a lifesaving intervention and then balance the recognized metabolic benefits of resuscitation against the detrimental effects of inappropriate fluid resuscitation. The finer points of this approach—performing hypotensive resuscitation based on radial pulse character, without a blood pressure cuff or

stethoscope; optimizing mean arterial pressure to maximize resuscitation while minimizing bleeding and rebleeding; optimizing the characteristics of resuscitation fluids and titration methods; and improved hemorrhage control methods—are all active areas of investigation. This outline will change with time, research and, most importantly, new experiences in tactical situations. The Special Operations medics performing casualty care in Operation Enduring Freedom currently use the approach described above. Early reports indicate that the logistical benefits are real and the medical outcomes remain favorable. These concepts are contingent on providing and sustaining appropriate levels of training and proficiency. This treatment algorithm represents the best of current thinking to allow the combat medic to provide state-of-the-art combat casualty care on the battlefield and, in addition, establishes a framework for future improvements.

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